SOME EXPERIENCE IN THE DEVELOPMENT OF THE OIL ENGINE[1]

By F. B. Leopold[2]

The title of this paper might indicate an intention on the part of the author to impart some knowledge to this Association. It is with regret that he is forced to proclaim that he had no option in selecting the subject. For some inscrutable reason, the Committee of the Water Works Manufacturers Association assigned this subject to a person who knows nothing about an oil engine from a technical standpoint. The author knows what one looks like and also has some idea of the cost of developing a successful engine, and if it be the idea of the Committee that the author should point out ways in which those who have a superfluous amount of the coin of the realm might dispense it, then possibly their object may be accomplished.

It is generally recognized that Dr. Diesel, a German engineer, is the father of the internal combustion engine using heavy oil, and his original patent is dated in 1892, although there were various attempts made in the line of development for many years previous to that time. An engine was actually built in 1680, and although it did not prove a success, it was probably the first step in its development. In 1791, an Englishman, John Barber, built an engine made to use gas distilled from coal, and from that time on to 1866, when Otto obtained his first patent, there were several attempts made. Diesel, however, was undoubtedly the father of the present successfully developed engine. Although his first patents were obtained in 1892, it was not until 1898 that a commercial engine was produced.

In 1898, Adolphus Busch became interested in this engine and secured the rights for the United States. The first engine built was a 60 H.P. unit. During the first few years, however, the progress was very slow and the result unsatisfactory. It is really only in the last ten or twelve years that this type of engine has come into its own

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in European countries, and is just beginning to be recognized as the coming power unit in this country. It is altogether probable that the abnormal increase in the price of coal caused by the war conditions was the greatest single element in arousing interest in the heavy oil engine, and has made for a tremendous impetus in its development.

Up to five years ago there were probably not to exceed four or five concerns building internal combustion engines using heavy oil as their fuel. At the present time, there are sixteen builders of Diesel engines and thirty-five establishments building various types of so-called semi-Diesel or low-compression heavy oil engines. Some of them have been on the market for a number of years, and are now turning out engines in large quantities, operating with great success. Others are in various stages of development work.

Among the main successful builders of the Diesel type of engine are the Busch-Sulzer Company, which was the first to engage in this work, The McIntosh & Seymour Company, William Graff & Sons and New York Ship Building Company, which with others, are building engines ranging from 200 H.P. to as high as 2000 H.P. each.

Of the builders of the semi-Diesel type, the concerns longest engaged in this line are the August Mietz Corporation, Fairbanks-Morse Company, Bessemer Manufacturing Company, the Burnoil Engine Company and St. Marys Engine Company. Of the thirty-five concerns building the so-called semi-Diesel engine twelve are operating under the Hvid-Bronz patents, and this is the type of engine that the author has had such experience with as he possessess.

This type of engine is different in its principles of operation from either the Diesel or the semi-Diesel. The essential features of difference are in the method of supplying the fuel. In all cases the fuel is ignited by the heat of compression, but the method of starting and applying the fuel to the various types is essentially different.

In the full Diesel, the fuel is applied with a pump at extremely high pressure through a needle valve through which the fuel is forced by an air pressure varying from 800 to 1000 pounds, which breaks it up into fine particles, so that when the heat of compression is applied it is completely consumed.

In the semi-Diesel, so called, the fuel is dropped on to a pan or bulb which is heated. The fuel is vaporized by the heat. After the engine is started, this bulb is maintained at a high temperature by the heat of compression sufficient to continuously vaporize the fuel, but in starting, it often requires from ten minutes to half an hour to heat

the bulb by a torch sufficiently, so that the fuel will be vaporized when coming in contact with it.

The Hvid-Bronz type of engine draws the fuel into the cylinder on the suction stroke of the engine, or rather it draws it through a small valve into a cup. The compression stroke then heats up this cup and generates a pressure inside of the cup which blows the fuel out and atomizes it into the cylinder, when it is ignited. The semi-Diesel engines operate on a lower compression pressure, but are not as economical in fuel consumption as the Bronz-Hvid or Diesel type.

The author became interested in this proposition by reason of having become interested in a shop which at the time was manufacturing material for war purposes, and it became essential to find some product for permanent development. In looking over the field, the future of the oil engine seemed extremely promising, and it is the author's belief that this industry is just in its infancy.

The great advantage of this type of motor for both stationary and marine purposes is so obvious that temporary discouragement cannot hold back its development. On the other hand, there are many problems to be solved. Those apparently who have given it the greatest technical and practical study of many years, find difficulties which they are unable to foresee, and which, while small in themselves, are of the most vital importance in the successful operation of the engine.

Figure 1 illustrates a four-cylinder engine, the first built by the shop mentioned. The design of the completed engine is exactly as it was on the drawing board, as far as all outward appearances are concerned. All the changes that have been made in the development and experimental work have been entirely in the method of applying the fuel to secure the determined calculated exact distribution and consumption, which means the success in operation and the efficiency of the completed machine.

In the preliminary investigations in the oil engine field, after reaching a determination that this was a promising business, the author, in connection with the engineers, looked over many different types of engines that were being developed and being built. The services of an engineer were secured who had many years experience, both in European and American practice, in the design of Diesel engines, and who, the author believes, is one of the best oil engine engineers in the country.

The company was desirous of looking into future possibilities, and while up to that time the hot-bulb or low-compression type of engine

was most favorably known and had been built and used to greater extent than any other type of heavy oil engine in this country, it was finally concluded that, on account of its higher economy and apparently more satisfactory operation, the Hvid-Bronz type had the greater future promise. This engine is comparatively new but had

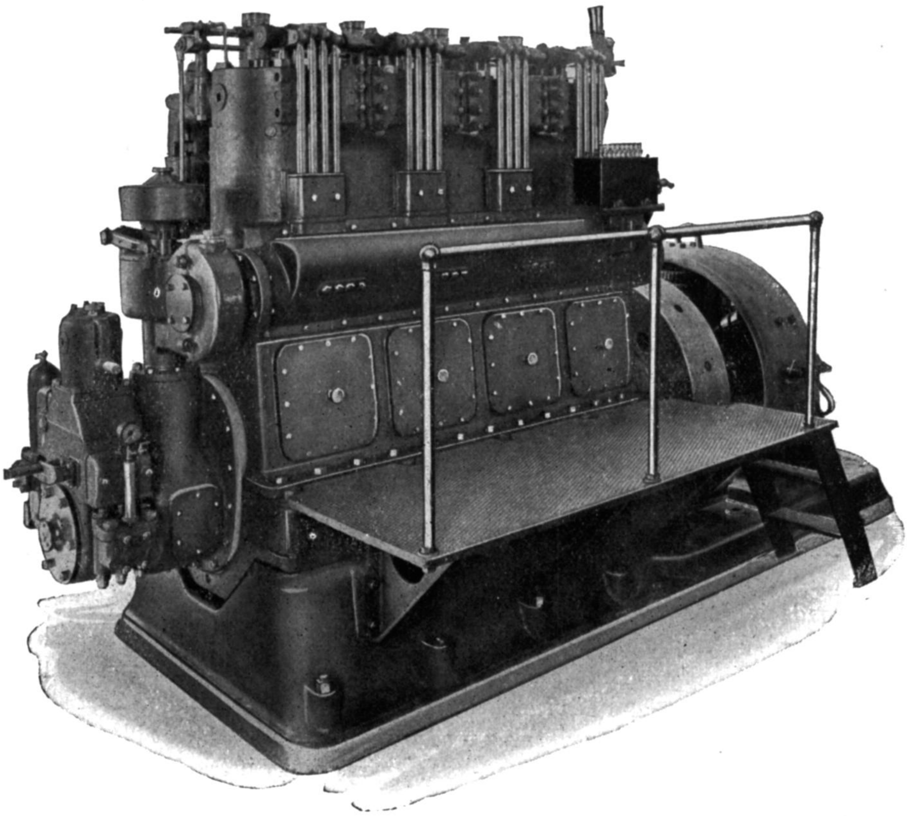

FIG. 1. THE 100-HORSE POWER OIL ENGINE, THE DEVELOPMENT OF WHICH IS OUTLINED IN THE PAPER

been built by one concern for about three years previously, and by one or two others for a shorter period and had been marketed in considerable quantity, and as far as could be learned was giving a very satisfactory account of itself.

Most of these engines were built in small single-cylinder units, although one concern was building a vertical multiple-unit engine

which seemed to be fairly satisfactory. Several others were developing a multiple-cylinder engine of this type. Therefore, after a thorough canvass of the field, a Bronz-Hvid engine of the multiple-cylinder type was selected and it was proposed to build the highest class engine of this type that could be turned out.

A single-cylinder engine of 5 or 6 horse power was purchased and a very long series of experiments made with it with results that were absolutely convincing. Although the engineer felt it was far from perfect, the operation of it was entirely satisfactory from a practical standpoint. This engine would operate on practically any kind of fuel that would flow in it, and, in fact, in the experiments four or five different fuel vessels were attached to the supply line to the engine, ranging from kerosene of the highest grade to the heaviest of crude oil, and it operated apparently equally well on any of them. During the period of operation it was not unusual to switch from one oil to the other.

This engine has no carburetors or electric spark plugs, nothing at all but the compression heat generated in the cylinders to ignite the fuel. The simplicity of its construction and operation was the appealing feature.

The investigation work was cleared up during the war period and the engine completely designed, but no work accomplished until after the close of the war. The patterns were made and the engine built completely in accordance with the designs and not a single change was made in its construction, as far as the general features were concerned. On its completion the engine was started in operation and was apparently a completed piece of mechanism. During this period the coöperation and advice of the patentee were given and on the day of completion with everything ready to place it on the test block for operation, he was more than pleased with the way it started. As the author had never seen an engine start before on the testing block, he was naturally very much elated, as apparently it was going to operate right from the start, and the Company was ready to do business and take orders. However, it was more than a year later before the engineers were ready to place the seal of their approval upon this engine, and during that period many anxious days and nights were spent in endeavoring to determine just what was required to make a successful machine out of it.

The principal difficulty, in fact the only difficulty, was apparently the inability to supply the fuel properly, so that a complete combus-

tion could be secured. In the initial run, although it was believed that the instructions and directions and formulae furnished by the patentee were followed faithfully, the exhaust discharge was a black column of smoke and at night this was superseded by a continual spurt of flame.

It did not require much knowledge of engineering to comprehend that this condition would not allow of operation for a very extended period of time, and in fact a few hours' operation found the fuel cups completely clogged with carbon. Then began the real work, and this dragged over a period of approximately a year.

During this period many engineers were visiting the works and offering suggestions, many who seemed to think that the troubles were trivial and might be corrected in a few days' investigation. The inventor himself, or patentee rather, laughed them away. However, the difficulties were multiplied by the number of cylinders, and the class of machine which it was desired to build.

It was discovered that there was a vast difference between building an engine of a single cylinder which would be satisfactory for ordinary power purposes, or the small factory, oil well or farm, and building a multiple-cylinder engine for a continuous 24 hour service where the greatest nicety of speed regulation was required, and where the possibilities of the engine being out of service at any time must be reduced to a minimum.

The introduction of the fuel into a single-cylinder engine was a comparatively simple proposition. The introduction of an equal amount of fuel into each cylinder of a multiple-cylinder engine, to maintain the same amount of work in each cylinder and thereby maintain uniformity of speed and power, was a very complicated proposition. It was often possible to get practically perfect combustion in one cylinder while the next cylinder could not be operated for any length of time without completely filling with carbon.

Many and various were the methods used for equal distribution of the fuel to the cylinders, for the principle of the Hvid engine is a gravity feed, the fuel being taken into the cylinder on the suction stroke of the engine. With a multiplicity of cylinders the fuel charge would vary in each cylinder, and this method of feed was finally abandoned as it was impossible to get a sufficiently equal charge necessary to secure regulation.

Pumping the fuel against the compression stroke on a somewhat modified principle from the Diesel was then employed and a hundred

other methods were then tried. In the end, a pump was used that is practically a measuring device, using a separate pump for each cylinder, which delivers the oil charge equally to each cylinder valve. It is then drawn into the cylinder on the suction stroke of the engine.

There was an absolute and definite ratio of the size of the cups to be used and the holes through which the fuel was discharged from the cups into the cylinder, and these ratios would vary somewhat with different characters of fuel. The very slightest variation from the determined areas either of the cups or the holes, or the location of the holes, would affect the operation of the engine to a great extent. It was only, however, after experimenting with hundreds of different sizes of cups and methods of adjustment, that a definite formula for making these fuel cups together with the sizes of holes they contain was obtained.

During the period while the engineers were making these various experiments, the author became interested vitally in determining whether this experience was at variance to any great extent from that of others in this line of endeavor. He found that other engine builders visited in the preliminary investigations and who, it was thought, had built marketable engines from the start, had gone through the same grievous experience, in fact, that some had spent thousands of dollars where the author's company had spent hundreds. Several concerns, after spending upwards of a million dollars experimenting on the problems trying to work out a successful engine, had finally been compelled to abandon it. Others had kept on until they had surmounted all difficulties and are now reaping the harvest, and will in the end have their money returned to them many times over.

The only satisfaction that the author has been able to derive from this phase of the matter is that the company was finally able to produce an engine which has been pronounced the finest of the Bronz-Hvid type in this country, and he has no doubt that many concerns entering this field have brilliant prospects of future returns from the money they may invest. He would, however, warn anyone from entering this work with the idea that they will design an engine even on well known principles and expect it to be a success from the start unless they simply reproduce the patterns in detail of some engine that is already on the market. This means that they must provide a large sum that can, if necessary, be devoted to carrying development work to a successful issue.

The possibilities of a heavy oil engine are limitless. In addition to the ordinary uses for central power stations, electric light plants, driving pumping units and general power purposes for marine work, all of which require, of course, units of fair size, there is untouched the vast use for the automobile, truck and locomotive.

The actual cost of producing a horse power of work with the Diesel engine is about one-third the cost of producing it in a steam engine. The initial cost of a power plant for stationary purposes, considering the cost of building, land, boiler and engine, would be practically the same. There are, however, many situations where the space occupied by a steam plant is unavailable. An oil engine will take up on an average from one-half to three-fourths of the same space that a steam engine would occupy, with the entire saving of space occupied by boilers, accessories and coal storage. The oil may be stored in a tank under ground, and the space required for it need no consideration whatever ordinarily.

The oil engine of the Bronz-Hvid type can be started instantly and stopped when you are through with the operation. The steam engine requires time to get up steam, and the fire must be kept ready for service continuously. For marine work, the space occupied in a ship, and the weight of the plant is enormously less, giving the same size vessel the additional cargo space as well as economy in operation. This is being realized very rapidly in marine service, and many ships are now being fitted with this type of motor.

In 1914 there were probably not to exceed twenty motor ships, as as ships driven by oil engines are known. Today there are upwards of 500 and every day sees additions thereto, many vessels of 10,000 to 12,000 tons.

In the April issue of the *Motorship* is given an account of the operation of the 7500-ton motor ship "Borgland," totalling 95,000 miles and nearly 2½ years time without a stop on account of engine trouble. It is stated that

It is a somewhat ironical circumstance that one of the first cargoes that the "Borgland" carried was a load of 7290 tons of coal from Norfolk, Va., to San Francisco, Cal. . . . . Preference among officers of the merchant marine for motor ships is significant, and in conversation with the "Borgland's" captain . . . . he remarked that the motor ship is far ahead of a vessel driven by steam machinery from the point of view of reliability, and referred to the fact that should one cylinder of the plant of an ordinary twin-screw Diesel engine give out, it is a comparatively simple proposition to put the cylinder out of action and carry on with the remainder at reduced

speed, which is so inconsiderable as to be negligible. As regards fuel tanks, the bulk of the oil is carried in four double-bottoms holding about 900 tons of oil. . . . The fuel consumption is about seven tons per day under normal conditions. It will thus be seen that the ship has a range of nearly 130 days without rebunkering.

As the average speed of this vessel is given at 10 knots per hour, it will thus be seen that she carries enough fuel to travel 31,200 knots, or 35,900 miles, or completely around the world, and nearly one-half the distance further. To do this with coal would leave little cargo space.

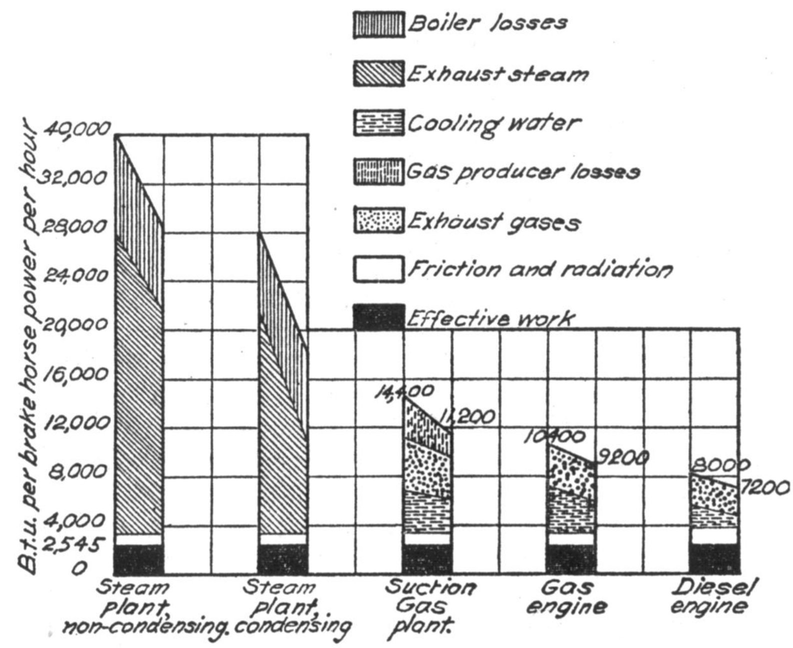

FIG. 2. HEAT BALANCES OF DIFFERENT TYPES OF ENGINES (HERBERT HAAS)

An oil engine will develop a horse power on one-half a pound of fuel oil per hour. A boiler requires four pounds of coal per hour, and some pumping plants require twice that quantity. This means from one-eighth to one-twentieth the weight of fuel to provide for. In times such as we have gone through in the past two or three years, what a strain off the minds of many plant engineers it would be to know that their storage capacity for fuel might be multiplied many times in less space than is now available.

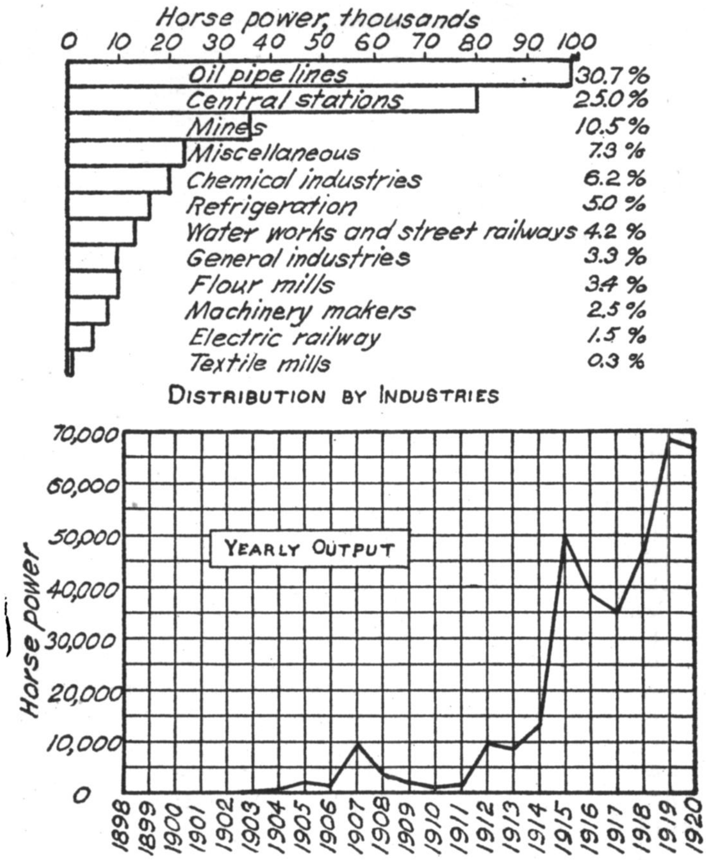

FIG. 3. DIESEL ENGINE DATA IN THE UNITED STATES. (L. H. MORRISON, *Power*, MARCH 1, 1921)

Distribution by states: horse power; New Hampshire, 1350; Massachusetts, 1030; Rhode Island, 550; Connecticut, 400; New York, 9505; New Jersey, 5080; Pennsylvania, 8045; Maryland, 2580; Delaware, 225; Virginia, 2055; South Carolina, 200; Georgia, 200; Florida, 9985; Kentucky, 1490; Tennessee, 100; Alabama, 100; Ohio, 4185; Indiana, 3590; Illinois, 7655; Michigan, 620; Wisconsin, 1865; Minnesota, 2675; Iowa, 2935; Missouri, 10,560; Arkansas, 2120; Kansas, 41,500; Nebraska, 5260; South Dakota, 4350; Louisiana, 12,000; Texas, 62,435; Oklahoma, 39,125; Montana, 420; Wyoming, 3320; Idaho, 460; Utah, 100; Colorado, 1320; Nevada, 780; Arizona, 23,240; New Mexico, 13,950; California, 4940; Alaska, 600; exported to Cuba, West Indies, etc., 23,480.

While this type of engine has not been developed successfully to take the place of the gasoline motor for automobiles, many engineers are working to this end, and it is but a question of time before it is accomplished. Considering the number of automobiles in the country, what a wonderful opportunity there is for the development of this type of motor to replace the gas motor for this work, doing away with electric spark plugs, carburetors, and all the troubles attendant thereto.

TABLE 1

Heat consumption and thermal efficiencies of different types of prime movers at continuous full load

TYPE OF PRIME MOVER	HEAT CONSUMPTION PER BRAKE H. P. HOUR	OVER-ALL THERMAL EFFICIENCY	SUPERIORITY OF DIESEL ENGINE*
	B.t.u.		
Noncondensing steam engine†	40,000–28,000	6.3– 9.1	5.60–3.60
Condensing steam engine using superheated steam†	28,000–16,500	9.1–15.4	3.60–2.30
Locomobile engine with superheated steam and reheater, condensing†	17,000–15,200	14.9–16.7	2.40–2.10
Steam turbine, superheated steam, 200 to 2,000 H.P.†	24,000–15,500	10.6–16.2	3.20–2.20
Steam turbine, superheated steam, 2,000 to 10,000 H.P.†	15,500–14,000	16.2–18.1	2.20–1.95
Gas engine without producer	10,400– 9,300	24.4–27.5	1.33–1.28
Suction gas engine‡	14,000–11,200	18.1–22.7	1.95–1.55
Diesel engine	8,000– 7,200	32.0–35.3	

* Figures in this column are to be used as factors with which to multiply values in preceding column.

† Figures include boiler losses.

‡ Figures include producer losses.

There is also the railway locomotive and this phase is now being considered by one of the largest locomotive builders in the country, which has for the last year or more been studying the possibilities of this engine as a motive power for railroad locomotives. Undoubtedly the time is not far distant when we shall see it in use.

Table 1, giving comparative costs of different prime movers, is from Bulletin 166 issued by the Department of the Interior, Bureau of Mines, and written by Herbert Haas. This bulletin contains some very interesting information on this type of engine, and is recommended to anybody interested in securing real information as to what may be accomplished with the oil engine.

The author has tried to give in a brief general way, without getting beyond his depth, some slight idea of the heavy oil engine, its development, and its possibilities as a power unit. What little knowledge he possesses has been acquired at a very considerable cost, and while he is just as thoroughly satisfied now as he was in the beginning that

TABLE 2

Comparative operating costs of different types of prime movers

*TYPE OF PRIME MOVER	KIND OF FUEL	AVERAGE COST PER 1,000,000 B. T. U.	COST OF 1,000,000 B. T. U. EFFECTIVE WORK	HEAT COST PER ONE EFFECTIVE H. P. HOUR
		cents	*cents*	*cents*
Noncondensing steam engine*	Coal	12	191–132	0.48–0.34
Condensing steam engine using superheated steam*.	Coal	12	132–78	0.34–0.20
Locomobile engine with superheated steam and reheater, condensing*.......	Coal	12	81–72	0.21–0.18
Steam turbine, superheated steam, 200 to 2000 H.P.*..	Coal and anthracite	12 11	113–74 104–68	0.29–0.19 0.27–0.17
Steam turbine, superheated steam, 2,000 to 10,000 H.P*	Coal and anthracite	12 11	74–67 68–61	0.19–0.17 0.17–0.155
Gas engine without producer	Natural gas, coke-oven gas or blast-furnace gas	15 7	62–55 27	0.16–0.14 .7
Suction gas engine†.........	Anthracite	11	61–49	0.16–0.14
Diesel engine...............	Petroleum	15–18	56–43	0.14–0.11

* Figures include boiler losses.

† Figures include producer losses.

any successful engine of this type will return splendid profits on any investment involved, he also knows that there is much still to be learned. He would advise anyone who may be considering this field, either to acquire something that is completed, or be prepared to spend a fair-sized fortune before expecting to see clear sailing ahead.

TABLE 3

Cost of various types of fuel

KIND OF FUEL	PRICE OF FUEL	HEATING VALUE PER POUND	ABSOLUTE HEAT COST PER 1,000,000 B. T. U.	AVERAGE HEAT COST PER 1,000,000 B. T. U.
		B. t. u.	*cents*	*cents*
Lignite	$1.00 to $2.50, ton of 2,000 lbs.	5,000- 9,000	10.0-14.0	12
Bituminous coal	$2.00 to 4.00, ton of 2,000 lbs.	11,000-14,200	9.0-14.0	12
Anthracite	2.50 to 4.00 ton of 2,000 lbs.	14,500	8.6-13.8	11
Fuel oil (petroleum)	0.75 to 2.25 barrel	18,000-19,000	12.5-37.5	15-18
Natural gas	0.10 to 0.75, 1,000 cu. ft.	900- 1,000	11.0-75.0	15
Blast-furnace gas	0.05 to 0.01, 1,000 cu. ft.	90	5.5-11.0	7
Coke-oven gas	0.02 to 0.05, 1,000 cu. ft.	450	4.4-11.0	7

TABLE 4

Data regarding amount of work performed by different types of pumping equipment

TYPE OF PUMPING PLANT	WORK PERFORMED IN LIFTING WATER	OVER-ALL EFFICIENCY
	foot-pounds per 1 B. t. u.	*per cent*
Steam; good operating conditions	54.5	7.0
Steam; best operating conditions	77.8	10.0
Steam; superheated steam used	93.4	12.0
Suction gas engine; good operating conditions	116.7	15.0
Suction gas engine; special conditions	147.8	19.0
Humphrey gas pump; special conditions	171.2	22.0
Humphrey gas pump; good operating conditions	156.0	20.1
Diesel engine; good operating conditions	225.6	29.0

Incidentally while the author and his associates have an engine that has now been in operation most satisfactorily for nearly a year, they spent a large sum to reach that stage, and had the choice of either stopping where they were, or getting more money. As money has been rather scarce for the last year, they quit for the time being the engine game, to give all their energies to the filter business. The author is more convinced than ever of the truth of the old saying that oil and water don't mix.